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RESISTANCE OF TEMPERED STEEL TO BRITTLE FRACTURE

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An analysis of breakdowns of steel airplane parts shows that the fracture is almost always of the brittle type without any traces of plastic deformation. The brittle nature of the fracture is not caused, however, by the low plasticity of the metal. In almost all cases, the mechanical properties (including relative elongation, compression of the transverse cross section and resilience) of the fractured parts satisfy all technical specifications. The greatest number of brittle fractures occur in those high-strength parts which are heat-treated (annealed and then tempered at 200 degrees centigrade) for tensile strengths of 160 to 180 kilograms per square millimeter.

Parts which are tempered at higher temperatures (around 500 degrees centigrade) and for tensile strengths of 110 to 130 kilograms per square millimeter undergo brittle fracture comparatively rarely, although with respect to plasticity and resilience the metal of these parts is practically the same as the metal of the parts treated for the higher tensile strengths. Thus, experience shows that plasticity and resilience do not alone determine the ability of a steel to resist brittle fracture.

Previous work by Ya. B. Fridman, Doctor of Technical Sciences, developed from the work of Academician N. N. Davidenkov, has shown that there are two basic strength characteristics, namely, maximum resistance to normal stresses, or resistance to break, and maximum resistance to tangential stresses, or resistance to shear. The maximum resistance to normal stresses, upon which brittle fracture depends, cannot be determined by testing smooth specimens of structural steel because the maximum resistance to tangential stresses is considerably less

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in absolute value than the maximum resistance to normal stresses, and thus the break of smooth specimens under axial tension is always of a plastic nature. However, in notched specimens, the normal stresses are considerably greater in magnitude than in the tension of smooth specimens. In fact, the normal stresses per part are $2(R+1)$ times the tangential stresses, where R is the area of the notch in percent.

Due to the different physical nature of the two types of fracture (shear and break), the dependence of these strength characteristics upon the various factors in heat treating, smelting, or alloying of steel may be not only different but often even diametrically opposite. The diagrams of mechanical state proposed by Fridman described the dependence of the type of fracture of parts or specimens upon the form of the stress state and the maximum resistance of the steel to normal and tangential stresses. Illustrations of these diagrams of mechanical state show that instrument steel fractures from shear under torsion and from break under tension or bending; that high-strength structural steel fractures from shear under torsion, tension, or bending of a smooth specimen, and from break under tension or bending of a notched specimen; and that medium and low-strength structural steel fractures from shear from torsion tension, or bending of smooth or notched specimens.

When the hardness is increased, the resistance to tangential stresses increases, while the resistance to normal stresses, as a rule, decreases. This explains why high-strength steels which have considerable plasticity in the testing of smooth specimens undergo brittle fracture from normal stresses in the testing of notched specimens. Thus, hardness, which is connected physically with the ability of steels to resist tangential stresses, cannot be used to evaluate the ability of a steel to resist normal stresses.

A general rule has been established which shows that with an increase in the tempering temperature and, consequently, a lowering of the yield strength, the resistance to tangential stresses decreases while resistance to normal stresses increases. This general rule was checked by bending tests of cylindrical, sharply-notched specimens. This type of specimen ensures brittle fracture from normal stresses in almost all high-strength steels. The graphs drawn for the dependence of the brittle strength of Chromansil steel and the chrome steels 26Kh and 38Kh upon the tempering temperature showed that the brittle strength increased with an increasing temperature up to 500 degrees centigrade for all three steels. Thus, the rule was confirmed.

This rule, however, is not quite absolute, since the brittle strength of a steel depends upon the metal's capacity for plastic deformation as well as its ability to resist normal stresses. This was proven by tests of certain rustions or structural steel (42KhA, 44KhNMA) which exhibited tremendous drops in brittle strength for the tempering temperature interval 300-400 degrees centigrade. A substantial decrease of the plasticity of the steels was noted for the same temperature interval both for torsional and bending tests of Menazhe specimens. The interconnection of the two factors was further demonstrated by a test in which a steel (30KhGSA) which did not exhibit a drop of brittle strength for tempering at 300 degrees centigrade and testing at room temperatures did show this drop to an increasing degree when tested at temperatures of minus 70 and minus 193 degrees, i.e., when the steel was less plastic.

A third factor influencing the brittle strength of a steel is its alloying. Previous tests by Potak and Bushmanova showed that chrome and nickel increase the brittle strength while phosphorus and carbon decrease this characteristic.

Probably the most important result of these tests is that they established that heat treatment of steel parts for high-yield strength reduces their ability to resist brittle fracture, despite the fact that the plasticity and resilience remain high. Thus, the use of steels treated for high-yield strengths for butt joints, bolts, and other parts having notches or sharp variations of cross section is undesirable.

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